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Price elasticity, block tariffs, and equity of natural gas demand in China: Investigation based on household-level survey data

Shipei Zeng [a, b], Zhan-Ming Chen [b, c, *], Ahmed Alsaedi [c], Tasawar Hayat [c, d]

[a] School of Economics, University of New South Wales, Sydney, NSW 2052, Australia
[b] School of Economics, Renmin University of China, Beijing 100872, China
[c] NAAM Group, Faculty of Science, King Abdulaziz University, Jeddah, Saudi Arabia
[d] Department of Mathematics, Quaid-i-Azam University, 45320, Islamabad, Pakistan

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ABSTRACT:

On the basis of a newly established database from the Chinese Residential Energy Consumption Survey, this paper estimates the price elasticity of natural gas demand for the households and investigates the factors that affect residential natural gas consumption in China. To address the endogeneity problems, the non-residential natural gas price has been adopted as the instrumental variable for residential natural gas price. Results demonstrate that the natural gas demand of Chinese households respond significantly to price change, with an overall price elasticity coefficient of −0.898. In the meanwhile, 1% increase in family members would cause 0.159% rise in natural gas demand, and household in the south consumes 28.8% more natural gas than that in the north. Recognizing the heterogeneity of residential natural gas price elasticity for different households, quantile regression technique has further been applied to analyze the distributional effect of natural gas consumption. The simulation suggests that the Gini coefficient drops from 0.49 to 0.40 after introducing an increasing block tariff scheme to replace the original flat tariff system, confirming a price reform has potential to improve the energy equity situation by reshaping the energy consumption pattern.

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1. Introduction

The rapid economic growth in China has been accompanied with a dramatic rise in energy consumption, leading to much concern on environmental issues such as air pollution and greenhouse gas emissions. To deal with such issues, implementing energy structure transition with promotion of clean energy usage becomes one of the key targets of China's recent energy reform strategy. Natural gas has been considered as a promising energy source to replace coal, which has been the dominant energy type as well as emission source in China. For example, the development of natural gas industry has been emphasized by the government as an important initiative to encourage green and low-carbon energy (The General Office of the State Council of China, 2014). Under such background, natural gas consumption had soared significantly from 24.5 billion cubic meters in 2000 to 170.5 billion cubic meters in 2013 with an annual rate over 16%. In accordance with this trend, natural gas consumption of China has attracted increasing attention in the literature (Li et al., 2010; Yin and Wang, 2012; Li and Wang, 2013; Yang and Niu, 2016).

Along with the restructure of the country's energy pattern, the Chinese government also attempts to reform its energy pricing mechanism in order to construct an efficient and sustainable energy market. The price reform for the natural gas market includes two major parts: (1) apply a market-based pricing system to determine industrial and commercial natural gas prices; and (2) apply a regulated increasing block tariff (IBT) system to determine residential natural gas price. When the former system tries to improve efficiency in natural gas production and consumption based on market power, the latter one pays more attention to energy equity in order to make the natural gas industry sustainable. The IBT system was first applied in 2011 in two pilot provinces. After a four-year pilot experiment, all cities with residential natural gas supply had been required to adopt the IBT system in 2015 (The National Development and Reform Commission, 2014a,b).

The promotion of the IBT system will introduce fluctuations on residential natural gas price because the previous flat price is replaced by differentiated prices. Zhang et al. (2012) found that the fluctuations would significantly affect the basic living condition of

* Corresponding author. Department of Energy Economics, School of Economics, Renmin University of China, Beijing 100872, China.
E-mail address: chenzhanming@ruc.edu.cn (Z.-M. Chen).

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households as natural gas is one of the inelastic energy products and living necessities. They believed that raising natural gas price would lead to unendurable expenses on natural gas that residents could hardly afford. The impact of the IBT reform therefore deserves accurate evaluation before implementing new pricing policies and thus controlling residential gas consumption, and the estimation as well as the application of natural gas price elasticity would assist to resolve this issue (Gong and Geng, 2008; Yin, 2014). Especially, the discriminating price system brings different impacts to households with different natural gas demand because of the heterogeneity of price elasticity. Therefore, it is important to understand not only the overall effect (i.e., to treat all consumers as a collective group) but also the distributional effect (i.e., to analyze from the perspectives of different individuals) of the IBT reform. However, insufficient attention has been paid to the latter effect in previous literature, mainly due to the fact that micro level data required for such analysis were missing.

Thanks to a newly established household-level energy consumption dataset (Zheng et al., 2014), this paper conducts an empirical investigation to analyze the price elasticity of household natural gas demand and study the distributional effect of the IBT reform of China. The remaining part is organized as follows. Section two reviews the literature. Section three introduces the econometric models and database adopted in this paper. Section four demonstrates the empirical results, highlighting the distributional effect of the IBT reform using the estimated price elasticities of different household groups. And the final section concludes.

2. Literature review

The literature on measuring energy price elasticity has been developing since the early effort by Nerlove (1958). Depending on the complexity of the analyzed system and the data availability, existing research adopted either single or multiple variables to study the relationship between energy consumption and energy price. A fundamental method is simply to treat energy price as the single determinant of energy consumption (see, for example, Luchansky and Monks, 2009). Brown and Phillips (1989), and the later follower Fan and Hyndman (2011) took the lagged energy price into the analysis. Taking into account the substitution and complementary effects, prices of related energy products were added to the estimation models (see Gundimeda and Köhlin, 2008; Jamil and Ahmad, 2011; and Arthur et al., 2012). Income level, measured by Gross Domestic Product (GDP) on the macro-economic scale or by household income on micro-economic scale, was also considered as one of the important determinants of energy consumption (Krichene, 2002; Cooper, 2003; Türkekul and Unakıtan, 2011; Lim et al., 2014). Apart from the price and income factors, household size (Gundimeda and Köhlin, 2008), education level of family members (Darby, 2006), living regions (Kaza, 2010; Romero-Jordán et al., 2016), and a number of other variables had been considered to identify energy price elasticity in previous research.

In terms of estimation model, different econometric techniques had been implemented in the literature to improve the accuracy of energy price elasticity measurement. The ordinary least square (OLS) method has been commonly used in the elasticity analyses (Brown and Phillips, 1989; Ramcharran, 2002; Arthur et al., 2012), which sets up the linear regression model of explained variables and explanatory variables. With energy consumption and energy price in natural logarithm form in the OLS model, the regression coefficient can be directly interpreted as energy price elasticity. The co-integration and the error correction model (ECM) are also frequently applied to deal with possible endogeneity and simultaneity in the estimation (Krichene, 2002; Narayan et al., 2007; Crôtte et al., 2010; Türkekul and Unakıtan, 2011; Jamil and Ahmad, 2011; Lim et al., 2014). Cooper (2003) as well as Lin and Zeng (2013) used the partial adjustment model, adding the lagged energy consumption into the set of explanatory variables. Gundimeda and Köhlin (2008) estimated the fuel demand elasticities through almost ideal demand system which was based on the expenditure structure. Other econometric methodologies, for instance the general to specific approach (Rao, 2007) and the autoregressive distributed lag model (Fatai et al., 2003), have also been employed to study energy price elasticity.

There are emerging concerns on the price elasticity of energy consumption in China in recent years. A series of literature tried to estimate the energy elasticity of China from the macro-economy perspective (Yao, 1993; Yang, 2003; Shi, 2005; Wu, 2006; Xia and Tang, 2006; Deng and Wu, 2009; Jia and Jin, 2014; Liu et al., 2016). Investigations focusing on household energy price elasticity are relatively insufficient (Feng et al., 2009; Gao et al., 2012; Sun and Lin, 2013; Zheng et al., 2014; Sun and Ouyang, 2016) since micro level energy consumption data were not well developed in China. However, the endogeneity problems have not been satisfactorily addressed in the aforementioned studies, i.e., authors either neglected the existences of the endogeneity problems (which left the problems unsolved) or conducted regressions based on subsample groups (which failed to maintain the integrity of the already limited information). Comparing with the existing studies, this paper attempts to estimate the household natural gas price elasticity of China by: (1) applying instrumental variable to diminish the effect of endogeneity, (2) conducting quantile regression to make the best use of the available information, and (3) adopting a newly established household-level energy consumption dataset. The employed techniques and data source are deemed to provide a more accurate and comprehensive estimation on China's household natural gas price elasticity, which will be used to analyze the distributional effect of the IBT reform on different consumption levels in this study.

3. Methods and data

3.1. Basic model specification

By synthesizing the existing literature, the basic energy demand model is specified in this study as follows:

$$\ln c_i = \beta_0 + \beta_1 \ln p_i + \beta_2 \ln y_i + \beta_3 hs_i + \beta_4 da_i + \beta_5 edu_i + \beta_6 prov_i + \varepsilon_i \tag{1}$$

where the sub-index i stands for household; c denotes natural gas consumption; p denotes the prices of a set of energy types including natural gas, electricity, and liquefied petroleum gas (LPG); y denotes household income; hs denotes household size; da denotes total dwelling area of the house; edu denotes education level of the representative member of the family; and $prov$ captures the fixed effects of various provinces. By using the OLS method, Eq. (1) can be applied to estimate values of the fundamental parameters using the household data.

3.2. Instrumental variable

Within the context of rapid energy consumption, the Chinese government attempts to reduce excessive gas consumption by posing a more reasonable, which means, higher, tariff level for energy consumers. Therefore, a rise in natural gas demand would simulate price increase, leading to reverse causality. In addition,

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